POSITION AND SHAPE OF THE VENUS BOW SHOCK: PIONEER VENUS ORBITER OBSERVATIONS

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Abstract. In this study magnetometer data from the Pioneer Venus Orbiter is used to examine the position and shape of this planet's bow shock. Utilizing crossings identified on 86 occasions during the first 65 orbits a mean shock surface is defined for sun-Venus-satellite angles of 60-110°. Both the shock shape and variance in location are found to be very similar to the terrestrial case for the range in SVS angle considered. However, while the spread in shock positions at the earth is due predominantly to the magnetopause location varying in response to solar wind dynamic pressure, ionopause altitude variations can have little effect on total obstacle radius. Thus, the Cytherean shock is sometimes observed much closer to or farther from the planet than previously predicted by gasdynamic theory applied to the deflection of flow about a blunt body which acts neither as source nor sink for any portion of the flow.

Introduction

Planetary bow shocks provide the outermost evidence of the deflection of the solar wind by a planet. Since the shock position and shape are determined by the size and nature of the planetary obstacle, bow shocks are a major source of information concerning the interaction of the solar wind with the planets, and hence their properties. Of the large objects in the solar wind probed thus far only the earth's moon has been found to possess sufficiently small magnetic moment and low electrical conductivity to absorb the solar wind to the point of not forming a bow shock (e.g., Schubert and Lichtenstein, 1974). In situ observations have demonstrated that the solar wind is diverted by magnetopause surfaces at Mercury (Ness et al., 1974), Earth (Sonett et al., 1960), and Jupiter (Smith et al., 1974) while the nature of the interaction at Mars is a matter of controversy with the shock crossings by Mariner 4 (Smith, 1969), Mars 2, Mars 3 (Dolginov et al., 1973), and Mars 5 (Dolginov, 1976) subject to varying interpretations (Russell, 1979; Intriligator and Smith, 1979). The Pioneer Venus Orbiter (PVO) has confirmed the conclusions of earlier American and Soviet missions (see Siscoe and Slavin, 1979) that the solar wind is stood-off by the Venusian ionosphere through the formation of an ionopause (Russell et al., 1979a; Wolfe et al., 1979, Brace et al., 1979).

For a "hard" obstacle (i.e. time stationary and not acting as a source or sink) the position and shape of the shock are a function of the magnetosheath flow which is then determined only by interplanetary conditions and the position of the boundary deflecting the flow (e.g. Spreiter et al., 1966). At planets where intrinsic magnetic fields stand-off the solar wind, such as the Earth and Mercury, the shock position is not constant due to both the changing interplanetary parameters and the variation in obstacle height in response to those changes (e.g. Fairfield, 1971; Slavin and Holzer, 1979). By comparison the change in subsolar ionopause altitude with varying solar wind conditions should be relatively small due to the exponential dependence of pressure on height in the ionosphere and the low ratio of ionospheric depth to planetary radius (Wolff et al., 1979). Accordingly, the hard obstacle model of the Venus solar wind interaction predicts that this shock should exhibit less variation in position relative to the planet than is the case at the Earth. However, a number of theoretical studies (Michel, 1971; Wallis, 1973; Cloutier, 1976; Perez-de-Tejada and Dryer, 1976) as well as observational studies (Russell, 1977; Romanov et al., 1977) have indicated that the ionosphere as influenced by its environment may be acting as a sink and/or a source for the magnetosheath with the possibility of giving rise to an effective viscosity at the interface between the two plasmas (Perez-de-Tejada, 1979). Such effects may be examined indirectly by studying the position and structure of the Venusian bow shock. For that reason this paper reports on the position of this shock as observed by the magnetometer experiment during the first 65 orbits of the Pioneer Venus mission and makes a direct comparison with similar data on the terrestrial bow shock.

PVO Shock Crossings

On December 4, 1978 the Pioneer Venus orbiter was inserted into a 24 hour orbit about the planet with an inclination to the equator of 105.6°, an apoapsis of 12 R_V, and a periapsis altitude of 140-200 km with a spin rate near 5 rpm (Colin, 1979). Hence, each day the satellite twice encounters the planetary bow shock, before and after its magnetosheath and ionospheric passage. For the first 65 orbits all distinct bow shock crossings have been identified using 64 second average quicklook data from the UCLA fluxgate magnetometer experiment which has been described elsewhere (Russell et al., 1979a). Out of a total of 130 passes shock positions were found for 86 with the lack of identification in the remaining 44 cases due to data gaps and/or the absence of a clear signature in the 64 second data. Multiple encounters took place on only 11 of 86 passes in which case the average position is used. It should also be noted that the use of the averaged data together with the requirement of an unambig-

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